March 15, 1955 J. B. JONES 2,704,034

PUMPING SYSTEM

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Fig. 1.

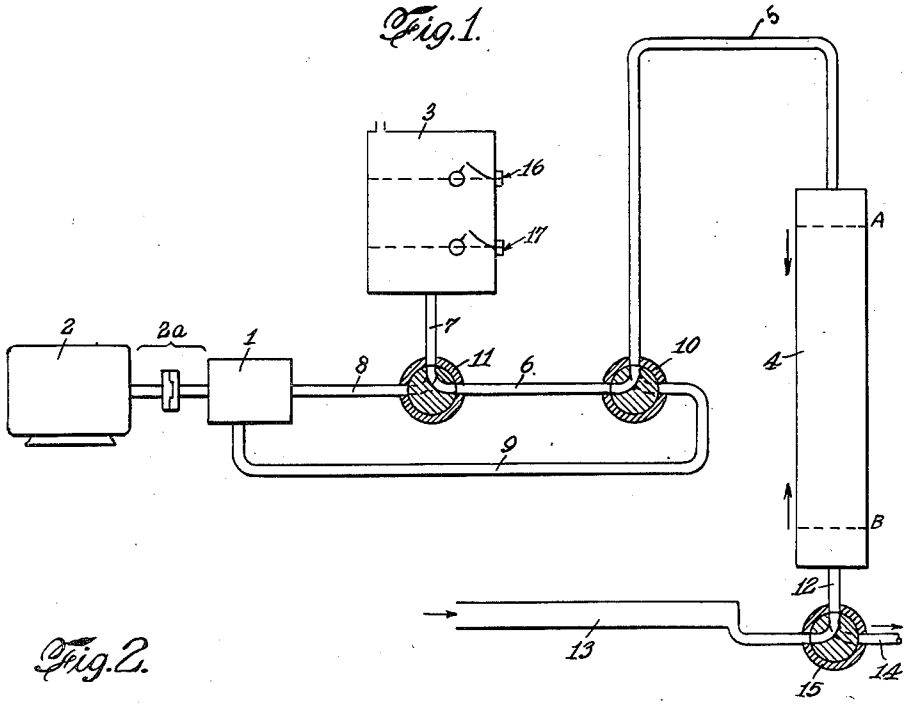


Fig. 2.

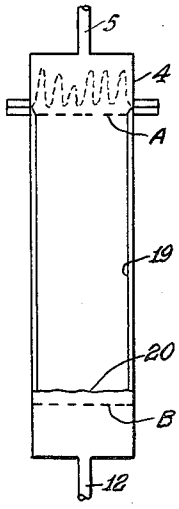
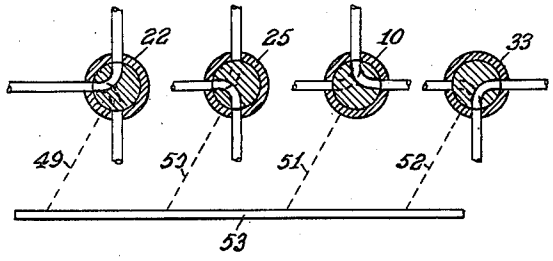


Fig. 4.



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Fig. 3.

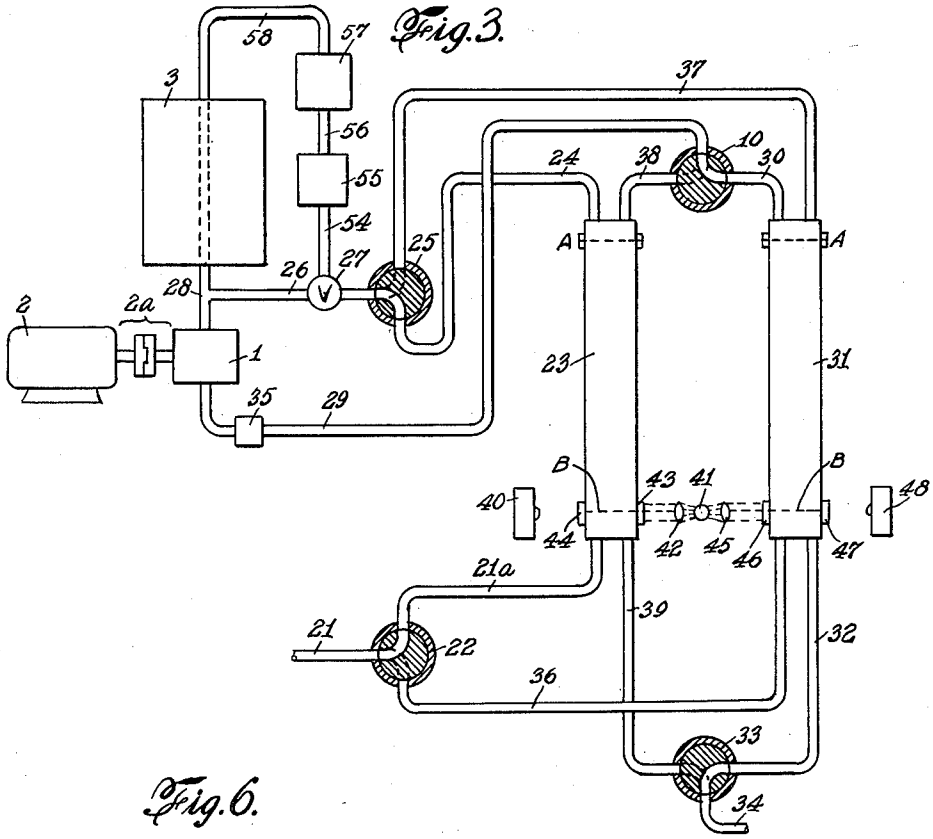


Fig. 6.

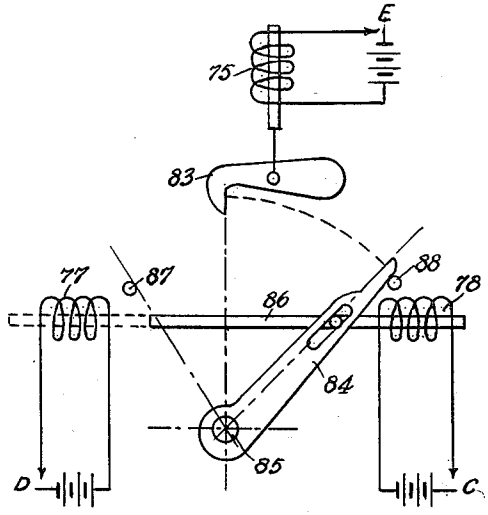
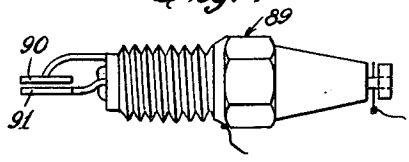


Fig. 7.



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Fig. 5.

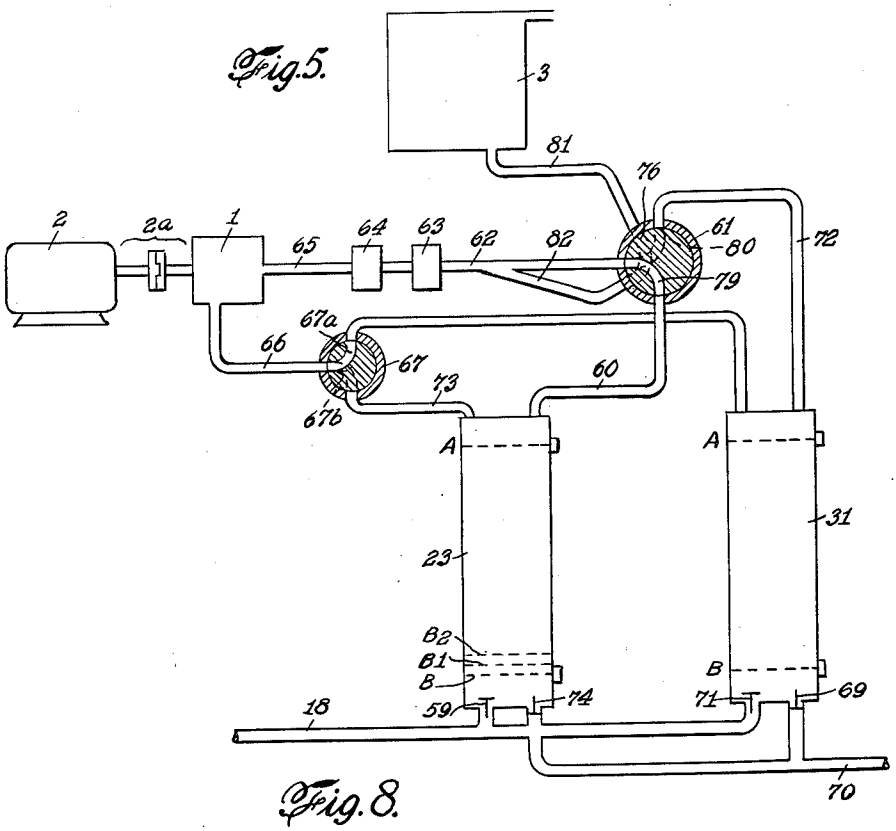
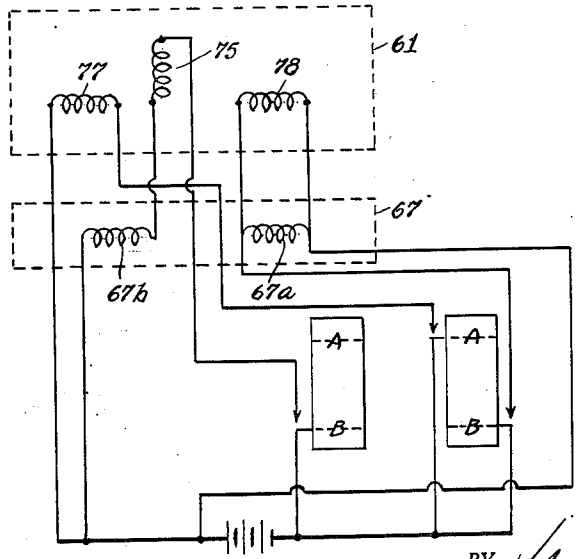


Fig. 8.



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2,704,034

PUMPING SYSTEM

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Application October 20, 1951, Serial No. 252,331

8 Claims. (Cl. 103—1)

The present invention relates to a pumping system and more particularly to a high pressure pumping system for liquids.

The pumping of liquids to high pressures, especially non-lubricating liquids such as water or certain biological or abrasive liquids, is difficult and expensive since the pumping equipment employed is usually heavy and often requires construction from certain suitable materials, e. g. stainless steel, so that the liquid being pumped is maintained free of contamination or that the pumping equipment itself is not deleteriously affected by the liquid being pumped, or that the pumping system may be easily cleaned.

The liquid being pumped to high pressure generally passes through pumps such as, for example, the slow moving piston type pumps or gear type pumps, and any single one of said types is not universally applicable for pumping certain liquids such as abrasive containing liquids, biologicals, sterile solutions, milk, liquid explosives, etc., since in each case certain controlled conditions must be maintained and the liquid being pumped determines the preferred type of pump that must be employed to meet the established pumping requirements.

Abrasive containing liquids will damage almost any type of existing pump.

Other liquids relating to the medical field must be sterile and cannot be brought in contact with certain metal parts, or they must not be heated by the pumping action or exposed to contaminating material or air.

In explosive liquids it may be desirable to provide a pumping action without excessive turbulence or without exposure to friction contact surfaces of moving pump components.

Furthermore, when the liquid being pumped passes through pumps as heretofore mentioned, it becomes necessary in many instances, e. g. with sterile liquids such as milk, to remove and disassemble the entire system for sterilization of the conduits and pump components.

Therefore, an economical universally applicable pumping system for any type of liquid required to be pumped to high pressure is desirable but has not been possible with the pumping systems heretofore known.

It is an object of the present invention to provide an economical universally applicable pumping system for all types of liquids required to be pumped to high pressure. It is another object of the present invention to provide a pumping system wherein a relatively inexpensive pump is employed to pump certain liquids heretofore requiring substantially expensive pumps. It is a further object of the present invention to provide a high pressure pumping system for liquids wherein a single type pump is capable of providing the pumping action for all types of liquids. It is a still further object of the present invention to provide a continuous type pumping system for pumping liquids to high pressure. Other objects of the present invention will become apparent from the description hereinafter following and the drawings forming part hereof, in which:

Fig. 1 is a diagrammatic representation of an intermittent type pumping system according to the present invention,

Fig. 2 is a diagrammatic representation of an embodiment of the present invention,

Fig. 3 is a diagrammatic representation of a continuous type pumping system,

Fig. 4 is a valve arrangement according to the present invention,

Fig. 5 is a diagrammatic representation of a continuous type pumping system including modifications thereof,

Fig. 6 is a schematic illustration of the components of a valve member according to the present invention,

Fig. 7 is an elevational view of a flow activating means of the present invention, and

Fig. 8 is an electrical circuit associated with the activating means and valves according to the present invention.

The invention deals with a pumping system including a closed system and an open system wherein the closed system is adapted to contain an easily pumped or first liquid, e. g. oil, while the open system is adapted to contain any kind of liquid or second liquid which is to be pumped to desired pressure, and the motivating force to the liquid to be pumped, i. e. the second liquid, to the desired pressure being provided by the liquid in the closed system by means of an exchange of pressure from the closed system to the open system.

According to Fig. 1, I provide a pump **1** of any suitable type for pumping liquids to the desired pressures, preferably to high pressures, e. g. a gear type or positive displacement type pump, and an operating means for the pump, such as motor **2** operably connected thereto as at *2a*. The pump **1** is a part of a closed system comprising also a container **3** for containing a determined volume of an easily pumped or first liquid, e. g. oil, or an excess of such liquid, a pressure exchanger **4**, conduits **5**, **6**, **7**, **8**, and **9** interconnecting said pressure exchanger, container and pump, and valves **10** and **11** for directing the flow of the liquid within said closed system. The open system comprises the pressure exchanger **4**, which is common to both the closed and open systems, conduits **12**, **13** and **14** interconnecting the pressure exchanger **4** to an inlet and outlet of the liquid to be pumped, or second liquid, to the desired pressure, and a valve **15** for directing the flow of the said second liquid.

The valves of both systems are preferably valves of the solenoid type but may also be mechanically operated valves as hereinafter set forth.

In operation, the second liquid under some pressure and preferably a controlled substantially low pressure enters the inlet to the open system through the conduit **13** and through the inlet port of valve **15** until the said second liquid displaces a certain volume of the first liquid outwardly of the pressure exchanger **4** to a designated position A spaced above a designated position B, as shown, and which positions are confined within the pressure exchanger. The certain volume of first liquid moving outwardly of the pressure exchanger **4** passes through the conduit **5**, the inlet port of valve **10**, conduit **6**, the inlet port of valve **11**, the conduit **7** and into a container **3**. When the second liquid reaches position A in the pressure exchanger, the valves **11**, **10**, **15** and the pump **1** are either simultaneously or otherwise activated in suitable order thereby closing the inlet ports of the valves and opening the outlet parts thereof and initiating liquid flow. At this stage the pump, preferably a high pressure pump, draws the first liquid from the container through conduit **7**, valve **11**, the pump **1**, and forces it through the conduit **9**, valve **10**, conduit **5** and into the pressure exchanger **4** to a position B. The conduits **6**, **8** and **9** and the valves connected therein constitute a cyclic conduit arrangement through said pump. When the first liquid reaches position B, a certain volume of the second liquid has passed under an exchange of pressure from the first liquid to the second liquid outwardly of the pressure exchanger through conduit **12**, valve **15**, and through the outlet conduit **14**.

Although positions A and B, as hereinbefore described, determine when the pump is activated or deactivated respectively and when the ports of the valves are opened and closed, it is apparent that with this pumping system the liquid level in the container **3** may act, e. g. by means of float type switches **16** and **17**, to activate the solenoid valves and start or stop the pump when positions A or B are reached. Otherwise, a flow reversing and motor activating mechanism may be connected to positions A and B on the pressure exchanger **4**. Also, the liquid level in the container **3** may activate the motor **2** simultaneously with the valves.

In order for the pumping system to operate as described, i. e. to comprise a universally operable pump member and to be capable of an exchange of pressure, the first and second liquids must either be immiscible or a separation between the liquids must be maintained and the separation must be distinct and rendered capable of cooperation with the positions A and B. For example, when the closed system contains any liquid such as oil immiscible with the liquid of the open system and having a density difference therewith, such for example as water or certain abrasive or biological liquids, a meniscus is maintained between the two liquids and the said meniscus, in view of the immiscibility of liquids, moves from position A to position B and defines the open system with respect to the closed system in the pressure exchanger. This is possible since the resultant hydraulic pressure difference in the exchanger at the meniscus, i. e. at the area of separation, is always zero. If there is a small difference in the density of the first and second liquids, I may under certain circumstances further stabilize the said meniscus by either heating or cooling either of the liquids to increase the density difference at the meniscus interface. Regarding the universally applicable pump, it is apparent that only the first liquid operates in the closed system and the said liquid is preferably selected as such which is non-corrosive and may be easily pumped, e. g. a lubricant, which is not damaging to the pump members, and which is recycled within the closed system thereby obviating the use of expensive heavy pumps or pumps of certain critically prescribed metal construction, e. g. stainless steel, which necessitates frequent disassembling when corrosive, sterile or biological liquids of the nature of the second liquid passes therethrough. It is apparent that such second liquids do not pass through the closed system of my invention and that only the open system may require disassembly for cleaning, sterilization purposes, etc. Furthermore, in view of the difficulty of obtaining critical corrosive resistant metals, for example metal alloys of high nickel content, I may use only a minimum amount of such materials for my open system, e. g. in valve **15**, since the internal walls of the pressure exchanger **4** and conduits thereof may be provided with a layer of or sleeve of a corrosive resistant non-metallic material such, for example as a plastic or vitreous composition such as fused quartz and the like. This is possible because the open system is a simplified system requiring no complex moving components and, moreover, even an inexpensive stand-by open system may be employed in the event that the operating open system is in need of disassembly.

However, when the first and second liquids are of a miscible nature, I maintain a clearly demarked area of separation between the open and closed systems in the pressure exchanger by providing a movable impervious separator such for example as illustrated by Fig. 2. In Fig. 2, the separator **19** constitutes an artificial interface or boundary between the first and second liquids and in the form of an impervious sleeve, stocking, film or membrane having a closed end **20** movable between positions A and B or beyond these positions and preferably having its open end, e. g. perimeter or rim, secured to the pressure exchanger **4** at a location in the vicinity of the position A as illustrated or in the vicinity of position B. For example, an impervious bellows member may be utilized as a separator as long as an end thereof or diaphragm thereof is movable between the said positions A and B. The end or diaphragm or artificial meniscus **20** of the separator **19** is preferably freely floatable between positions A and B.

It is apparent from the foregoing description that the pumping system according to Fig. 1 is an intermittent system in that the liquids are intermittently pumped.

Fig. 3 illustrates a continuous type system according to this invention.

In operation under some pressure, e. g. a controlled comparatively low pressure, the second liquid enters the inlet conduit **21** of the open system, passes through the open port of valve **22**, through conduit **21***a*, into the pressure exchanger **23**, which corresponds to the pressure exchanger **4** as described, and moves a certain volume of the first liquid of the closed system in exchanger **23** outwardly thereof to the position A. The certain volume of the first liquid thereby passes through the conduit **24**, through the open port of a main valve **25**, and through the conduit **26** containing a normally open or auxiliary valve **27** leading to the conduit **28**, which leads to pump **1**. Since this is a

continuous system, pump **1** operates continuously and the first liquid leaving the exchanger **23** passes directly through the pump **1**, conduit **29**, the open part of another main valve **10**, conduit **30** and into the pressure exchanger **31**, which is preferably dimensioned to contain a volume equal to that of exchanger **23**, until the first liquid reaches position B of exchanger **31** and a certain volume of the second liquid in exchanger **31** passes outwardly thereof through conduit **32**, the open port of valve **33** and through the outlet conduit **34**.

When a separator or meniscus or diaphragm **20** in each of the exchangers reaches position A in exchanger **23** and simultaneously a corresponding meniscus or separator reaches position B in exchanger **31** the valves **10**, **22**, **25** and **33** are simultaneously activated or otherwise in suitable order thereby closing the open ports and opening the alternate ports of each valve, whereby the second liquid enters the inlet conduit **36** to the exchanger **31** to position A in said exchanger. A certain volume of the first liquid in exchanger **31** thereby passes through the conduit **37**, the valve **25**, through the normally open valve **37** and is recycled through the pump **1**, through conduit **29**, valve **10**, conduit **38** and into exchanger **23** until it reaches position B. When the first liquid reaches position B in exchanger **23**, the second liquid simultaneously reaches position A and a certain volume of second liquid has in the meantime passed outwardly of the exchanger **23**, through conduit **39**, valve **33** and through the outlet conduit **34**.

It is apparent from the above that the operation of the valves as set forth permits a continuous flow of the second liquid to pass through the outlet conduit **34** by a reciprocating pumping action or exchange of pressure, in the plurality of exchangers.

The container **3**, of Fig. 3, is in fact, according to the continuous system described, a reservoir ensuring at all times an adequate amount of first liquid to pass through the pump **1** as described. Therefore, in such a continuous system, since the liquid level of the container **3** will not function similarly to that of the intermittent system, I provide a reverse flow activating mechanism for the valves by associating such a mechanism directly with at least position B of one of the exchangers, although I may associate the activating mechanism with position B of both exchangers, or similarly with position A of one or both exchangers. Since the volumes of both exchangers are preferably corresponding volumes, it is apparent that I may also associate the activating mechanism with positions A and B of only one exchanger.

It is further apparent that I may use suitable float operated switches with the float particularly adapted to operate on the liquid to liquid interface at positions A or B, and of a type as described with respect to the container **3** of the intermittent system, to simultaneously or otherwise in suitable order operate the aforesaid valves. However, with the use of solenoid valves, I prefer to use a photocell **40** positioned for operation at position B of one of the exchangers or both exchangers as illustrated, whereby a source of light **41**, which may be directed by lens **42** provides a light radiation to pass through light transmissive window **43**, through the liquid content in the exchanger, out of the light transmissive window **44** and to the photocell **40**, which activates the valves as heretofore described. Likewise, I may provide an additional lens **45**, windows **46** and **47** and a photocell **48** for the other exchanger.

I may, however, manually operate the valves **22**, **28**, **10** and **33** where continuous flow of the second liquid is desired for only limited periods by positioning the valves preferably in a substantially linear arrangement as shown by Fig. 4 and mechanically connecting the valves, for example, at **49**, **50**, **51** and **52**, to a common lever **53**. In the manual arrangement of valves, I may dispense with the use of photocells and visually determine the position of the meniscus **20** through either of the windows, for example, window **44**. With such a valve arrangement, therefore, it is apparent that I may electrically or manually activate the flow depending upon the desired duration of the continuous flow.

In order to more easily determine the position of the meniscus either visually or with photocells associated with the exchangers, I prefer to color or dye the first liquid if its original color is too light.

In the case of pumping sterile second liquids to high pressures I may protect the contamination thereof from

the first liquid by sterilizing the first liquid for a designated period by manually closing the normally open valve 27 of the closed system and diverting the flow of said first liquid through the conduit 54, sterilizer 55, conduit 56, heat exchanger 57, whereby the first liquid is cooled to a suitable operating temperature, and through conduit 58 to the container or reservoir 3 and to pump 1. After a suitable sterilizing period, I thereafter again open the valve 27 to its normally open position and permit the first liquid to flow according to its normal channels.

Alternatively, I may connect sterilizing and heat exchanging members in the open system similar to the members 55 and 57 in the closed system as illustrated, or I may connect such sterilizing and heat exchanging members to a conduit of the closed system and a conduit of the open system.

Although the liquid flow through the open and closed systems has been particularly set forth as described with respect to Fig. 3, it is possible that the activating mechanism or means, located at e. g. positions A and B of the pressure exchangers, will not continue to automatically activate the valves of the closed system in proper order or simultaneously because, due to possible pump or gland, seepage, etc., the liquid in the first system may lose some of its volume or may be otherwise so affected that the separator in one pressure exchanger may reach position A before the separator in the other exchanger reaches position B. Such a situation will establish an unfavorable hiatus which may develop a fluctuation in the outward flow of the second liquid under high pressure.

I overcome such a situation by providing a particular automatic flow central valve means in the closed system according to Fig. 5.

According to Fig. 5, and under normal operating conditions, a second liquid enters the open system through inlet conduit 18, through check valve 59, into the pressure exchanger 23 to position A whereby the said second liquid displaces the first liquid of the closed system outwardly of the said pressure exchanger, through conduit 60, through an open port of the flow control valve 61, conduit 62, to which is connected the diagrammatically illustrated sterilizer 63 and heat exchanger 64, said sterilizer and heat exchanger being normally by-passed by the flow of liquid therethrough and operate as described with respect to Fig. 3 and then through conduit 65, through pump 1, conduit 66, the open port of valve 67, and conduit 68 into the pressure exchanger 31 to position B displacing the second liquid outwardly of exchanger 31 through check valve 69 and outlet conduit 70. The liquid of the closed system normally reaches position B of exchanger 31 at the same time that the liquid of the open system reaches position A of exchanger 23, whereby valves 61 and 67 are activated allowing a reciprocal flow or reverse flow between the exchangers so that the second liquid enters the exchanger 31 through check valve 71 and the first liquid in exchanger 31 is forced outwardly thereof through conduit 72 through the control valve 61, conduit 62, pump 1, conduit 66, valve 67, conduit 73 and into exchanger 23 to position B, whereby the second liquid in said exchanger passes outwardly thereof through check valve 74 and conduit 70.

However, if a hiatus develops in the reciprocal liquid action between the aforesaid positions A and B, it may be that the first liquid in one of the exchangers, e. g. exchanger 23, reaches only positions B^1 or B^2 when the second liquid in the other exchanger, e. g. exchanger 31, reaches position A. To overcome such an unfavorable situation, the valve 61 is provided as a control valve particularly illustrated by Fig. 6.

According to Figs. 5, 6, and 8 the valve 61 is illustrated as a solenoid valve, although it may be a mechanically or motor operated valve as well, and comprises an intermediate stop position 75 cooperative with a valve port 76 of valve 61 as shown by Fig. 5.

Under normal conditions, i. e. when positions A of exchanger 31 and position B of exchanger 23 are reached simultaneously, the switches C, D and E of solenoid members 75, 77 and 78 are energized or deenergized respectively to permit the valve ports 79 and 80 to operate in accordance with the reciprocal first liquid flow into and out of the exchangers as hereinabove described. However, when first liquid reaches only a position such as B^1 or B^2 while the second liquid in another exchanger has reached position A, the solenoid member 75 is not energized and the valve activating means at position A energizes the valve to move to an intermediate position cooperative with the valve port 76, which permits a certain amount of first liquid from the container 3 to enter into the closed system through conduit 81, port 76 and conduit 82, or conduit 62 depending upon the construction of port 76, in an amount sufficient to fill the closed system when the first liquid reaches position B, whereupon the solenoid members 75 and 67*b* of valve 67, as shown by Fig. 8, are energized to permit the port 79 to move into engagement with the normal flow conduits as hereinbefore described and the valve 67 is simultaneously energized to alter the course of the first fluid and to direct it to the exchanger whose volume of first liquid has been previously displaced.

In order to accomplish the aforesaid action of the valve 61, I provide the solenoid member at the intermediate position with a stop means or pall 83 cooperative with an arm 84 pivoted on the valve shaft 85 of valve 61 and moveably or otherwise connected to the solenoid rod 86 so that the said stop means aligns the port 76 into communication with the container 3 conduit and the conduit of the closed system. Other stop members 87 and 88 are provided to contact the arm 84 in order to align the ports 79 and 80 with the closed system conduits for the normal flow channels.

Fig. 7 illustrates one type of means for activating the said valves in accordance with the positions A and B as hereinbefore described. At such locations I may position a spark-plug type sensing or activating member 89 through the walls of the exchangers at the said positions in lieu of the photocell arrangement previously set forth. The spark-plug type activating member comprises a body portion and electrodes similar to the known type spark plugs but the electrodes are provided with spaced plates 90 and 91. Such a sensing or activating member is particularly applicable when the first or second liquids are of different electrical conductivity. For example, if the first and second liquids employed are oil and water, the circuit energizing the valves will close when water occupies the space between the electrode plates but will remain open when oil occupies the said space in view of the lesser conductivity of the oil.

Although I have particularly described the flow of the liquids in the open and closed systems, it is apparent that the scope of the invention may include variations in arrangement of the components of the system as long as the closed system operates as described in combination with the open system. For example, while the cyclic flow of the liquid in the systems may be caused to periodically reverse by means of the meniscus of separator position sensing devices, it is also possible to reverse the flow as a function of time by means of a timing device associated with the valves whereby the flow in either system is periodically reversed. Also, a further method for periodic reversal of the flow in either system may be provided by means of a metering device in either system, e. g. meter 35 or Fig. 3 so that the flow is periodically reversed after a specific volume or quantity of liquid has passed through any selected portion of either system.

What I claim is:

1. A pumping system for liquids comprising in combination a closed system, an open system and at least one pressure exchanger common to both of said systems, said pressure exchanger comprising a single substantially tubular chamber, said closed system comprising a pump member, valve means, a cyclic conduit arrangement leading through said pump member and said valve means, and conduit means leading from said pressure exchanger to said valve means of said closed system, a liquid lubricant filling said closed system, said open system comprising valve means, inlet conduit means and outlet conduit means connected to said pressure exchanger through said valve means of said open system, said closed system being connected throngh one portion of said pressure exchanger and said open system being connected through another portion of said pressure exchanger spaced from the portion to which said closed system is connected, a second liquid filling said open system, said liquid lubricant and said second liquid being immiscible, said open and closed systems being separated by the liquid interface between said immiscible liquids within said pressure exchanger, said interface being unrestricted and freely traveling along a major length of said cham-

ber, means for activating the valve means which are in fluid communication with said lubricant and second liquid at predetermined intervals, whereby a reciprocal flow of said liquid lubricant in said pressure exchanger provides an alternate reciprocal discharge of said second liquid from said pressure exchanger.

2. A pumping system according to claim 1, wherein a reservoir for containing said first liquid is connected to said closed system through said valve means.

3. A pumping system according to claim 2, wherein said valve means of said closed system comprises a plurality of valves, one of said valves being operatively connected to said reservoir and one of said valves being operatively connected to said pressure exchanger.

4. A pumping system according to claim 1, comprising a power source operably connected to said pump member.

5. A pumping system for liquids comprising in combination a closed system, an open system, and a plurality of pressure exchangers each common to both of said systems, each of said pressure exchangers comprising a single substantially tubular chamber having top and bottom portions, a liquid lubricant filling said closed system, said closed system comprising a pump member, means for reciprocally reversing the flow of said lubricant in said pressure exchangers, a cyclic conduit arrangement leading through said member and said flow reversal means, and conduit means leading from each of said pressure exchangers to said flow reversal means, said open system comprising valve means, inlet conduit means leading through said valve means to each of said pressure exchangers, outlet conduit means leading through said valve means from each of said pressure exchangers, said closed system being connected to one of said top and bottom portions of each of said pressure exchangers, said open system being connected to the other of said portions of each of said pressure exchangers, a second liquid filling said open system, said lubricant and said second liquid being immiscible, said open and closed systems being separated by the liquid interface between said immiscible liquids within said pressure exchangers, said interface being freely traveling along a major length of each of said chambers, means for activating the valve means which are in fluid communication with said lubricant and second liquid at predetermined intervals, whereby the reciprocal flow of said liquid lubricant between said exchangers provides an alternate reciprocal discharge of said second liquid from each of said pressures.

6. A pumping system for liquids comprising in combination a closed system, an open system and at least one substantially tubular pressure exchanger common to both of said systems, said pressure exchanger comprising a single chamber, said closed system comprising a pump member, valve means, a cyclic conduit arrangement leading through said pump member and said valve means, and conduit means leading from said pressure exchanger to said valve means, said valve means comprising a plurality of valves, one of said valves being a volume control valve having a pair of normal flow ports and a volume control port, a liquid reservoir and conduit means therefor connected to said volume control port, a liquid lubricant filling said closed system, means for activating the valve means which are in communication with said lubricant of predetermined intervals for reciprocally reversing the flow of said lubricant in said chamber, said open system comprising valve means, inlet and outlet conduit means leading through said valve means to said pressure exchanger, said closed system being connected to one portion of said pressure exchanger and said open system being connected to another portion thereof spaced from the portion to which said closed system is connected, a second liquid filling said open system, said liquid lubricant and said second liquid being immiscible, said open and closed systems being separated by the liquid to liquid interface between said immiscible liquids within said chamber, said interface being freely traveling along a major length of said chamber, and means activating the valve means in communication with said second liquid at predetermined intervals, whereby said liquid lubricant in said chamber provides an alternate reciprocal discharge of said second liquid from said chamber.

7. A pumping system for liquids comprising in combination a closed system, an open system, a plurality of pressure exchangers common to both of said systems, each of said pressure exchangers comprising a single substantially tubular chamber, said closed system comprising a pump member, a cyclic conduit arrangement leading between said exchangers through said pump member, a liquid lubricant filling said closed system, and means activating the valve means in fluid communication with said lubricant at predetermined intervals for reciprocally reversing the flow in said closed system between said exchangers, said open system comprising valve means to each of said pressure exchangers, outlet conduit means leading through said valve means from each of said pressure exchangers, a second liquid filling said open system, said liquid lubricant and said liquid being immiscible, said open and closed systems being separated by the liquid interface contact area between both liquids within the pressure exchanger chambers, said interface being freely traveling along a major length of each of said chambers, whereby the reciprocal flow of said liquid lubricant between said exchangers provides an alternate reciprocal discharge of said second liquid from each of said pressure exchangers.

8. A pumping system according to claim 7, comprising means for activating flow reversal in said chambers, said activating means consisting of electrical conductivity sensing elements positioned through the walls of said pressure exchangers, said activating means being electrically connected to said flow reversing means.

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